

MANGROVE SWAMP AND SALT MARSH COMMUNITIES IN SOUTHERN AUSTRALIA

M. KRATOCHVIL,* NOLA J. HANNON* AND LESLEY D. CLARKE*

(Plate x)

[Accepted for publication 23rd August 1972]

Synopsis

Vegetation maps of three areas close to Sydney indicate the diversity of the associations of the mangrove and salt marsh species and of their distributions with respect to the source of tidal flow. The floristics of this district and its major environmental characteristics are compared with those of localities in the other southern States of Australia.

NOMENCLATURE

Arthrocnemum australasicum (Moq.) Moss is not correctly applied to the plant thus named herein and throughout the series of related papers. For the present, it is probably best referred to as *Salicornia quinqueflora* Bunge ex Ungern-Sternberg, but this group is in need of revision (L. Johnson, pers. comm.).

Cladium junceum has now been transferred to the genus *Baumea* and is correctly cited as *B. juncea* (R.Br.) Palla.

INTRODUCTION

The rate of urban extension throughout southern Australia threatens maritime communities with severe disturbance, if not extinction. Many stands have already been eliminated, particularly within the past 30 years. Pollution is now prevalent in the majority of the remaining stands and yet our knowledge of these ecosystems, which are of particular interest, is very incomplete. Chapman's (1960) monograph clearly indicates the dearth of information for Australia where, as in other areas of the world, intertidal situations sheltered from wave action support mangrove and/or salt marsh communities.

However, such apparently cosmopolitan habitats do not support plant communities that are identical or even similar, despite the universal dominating influence of saline tidal flow in these situations. At least two major variants of these community types can be distinguished within the immediate vicinity of Sydney. Comparison of the floristics of these salt marsh communities with those even in Victoria and South Australia reveals marked differences. In addition, the limited comparisons that can be made of the performances of the same species in different areas of Australia suggest considerable intra-specific variation; for example, in *Avicennia marina* (Forsk.) Vierh. var. *resinifera* (Forst. f.) Bakh., McNaë (1966) records that in northern Queensland its seedlings require high light intensity and are killed by shade or mud cover; also that adults occur in situations where the salinity of the soil water is 9%. Beard (1967) has located a stand of *Avicennia* in north-western Australia completely isolated from the sea, situated 25 miles inland, which is presumed to be a relic from the last recession of the sea level thought to have occurred at least 2,500 years ago. Presumably *Avicennia* seedlings have satisfactorily established in this highly atypical habitat. Both of these reports contrast sharply with the environmental requirements for survival of *Avicennia marina* seedlings collected in the Sydney district (Clarke and Hannon, 1970). In a few isolated areas in the Sydney district, such as in South West Arm of Port Hacking, mature *Avicennia* individuals of only 1 m

* Botany School, University of New South Wales.

height occur in situations where at high tide the shoot system is completely submerged. Long, finger-like projections hang downwards from the stems and are exposed to the air at low tide. McNae (1966) points out that *Avicennia marina* occurs further south and in cooler temperatures in Australia than in Africa and Sauer (1965) notes that since it grows under a great climatic range all round Australia, its sparse geographic pattern presumably reflects unfavourable edaphic and exposure conditions.

It is apparent that the need for study of these areas is urgent and that all available information should be placed on record so that at the least, detailed descriptions of these communities may be preserved. The purpose of this paper is to record vegetation maps that were prepared in 1965, in the course of studies of these communities in the Sydney district, and also limited observations that have been made in similar habitats in several areas of southern Australia.

I. VEGETATION MAPS OF COMMUNITIES IN THE SYDNEY DISTRICT

Localities

The areas that are described here are located as follows:

(i) Woollooware Bay: the most southern arm of Botany Bay, 17.6 km due south of Sydney. The north-eastern shore communities in this arm have been studied in the greatest detail (Clarke and Hannon, 1967, 1969, 1970, 1971).

(Military Map Sheet $\frac{\text{South } 1.56}{\text{N.I.NE.NW}}$ Zone 8; Port Hacking. 1 Mile Series. Grid Reference 155970). The communities cover approximately 60 hectares.

(ii) Bonnie Vale: within the Royal National Park, 25.6 km due south of Sydney: near Bonnie Vale, along the eastern shore of Cabbage Tree Creek which empties

into Port Hacking. (Military Map Sheet $\frac{\text{South } 1.56}{\text{N.I.NE.NW}}$ Zone 8; Port Hacking. 1 Mile Series. Grid Reference 118878.) Approximately one-third of the area has been mapped.

(iii) Within Ku-ring-gai Chase, 20.8 km due north of Sydney: near Terrey Hills along the western edge of a tributary of Smith's Creek. (Military Map No. 417—Zone 8; Broken Bay. 1 Mile Series. Revised edition. Grid Reference 221394.) Approximately one-fifth of the area has been mapped.

Method

The communities at Woollooware Bay have been demarcated from aerial photography, but very much more detailed mapping was done in the other two areas. The method that was used in preparing these maps is as follows: A base line along an appropriate compass bearing was marked by posts located at 30.8 m intervals. A position which could be readily located by reference to a permanent external marker was selected as one end of the base line and the direction of the line was determined by consideration of its visibility from many points within the area to be mapped. A grid of areas of 30.8 × 30.8 m was outlined by placing transects at right angles to the base line. The boundaries of each floristically distinct area and the position of the conspicuous isolated individuals were measured with reference to the grid axes on 31 m length tapes and were mapped on graph paper using a scale of 2.54 cm = 15.4 m.

Description of the Vegetation

The maps and the details of the location of the marker pegs are given in Figs 1, 2 and 3 and show the present spatial relationships of the prominent species of these communities. The descriptions of the communities which have been recognized and used as mapping units are presented with the maps.

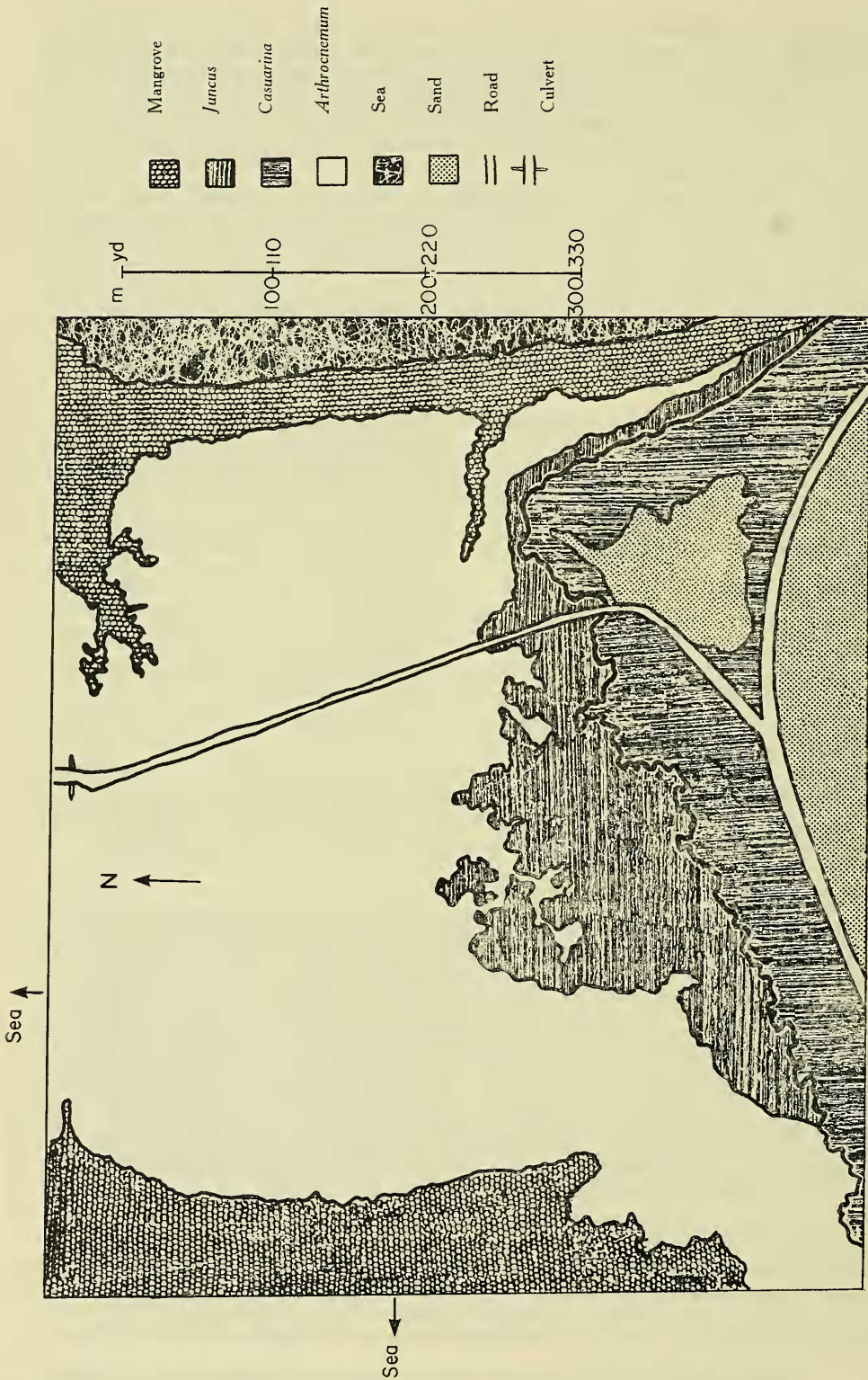


Fig. 1. Vegetation distribution at Woolooware Bay.

The area at Woollooware Bay displays narrow ecotones between the zones that cannot be accurately detected on the aerial photograph nor indicated on the map at this scale. This serves to indicate that the zones are very sharply demarcated and that the Woollooware Bay area contrasts in this respect with both of the other areas. In the maps of these latter areas, it is possible that small patches of herbaceous species amongst the *Juncus* may not have been detected owing to the marked intermingling of the species and the great differences in height of the components of these communities. Furthermore, in certain positions the borders of some of the communities can be delimited only subjectively and have been indicated by a dotted line.

Discussion

These are the first records of the communities at Woollooware Bay and at Smith's Creek, but a generalized map of all the Cabbage Tree Creek area was prepared by Collins (1921). Collins' map distinguished only three communities and was prepared without a compass (pers. comm.). In addition, no reference point was given and thus it is not possible to orient the 1921 map accurately to allow comparison with the present distribution of the species. A survey of Smith's Creek has since been made by Steenson and Barratt (1970).

The patterning of the species at Woollooware Bay is similar to the simple zonation described by earlier workers (e.g. Pidgeon, 1940) for this type of habitat. The intricacy of the pattern at the other areas has not previously been studied. At Woollooware Bay and other areas where the species are arranged similarly, extensive areas of sediments have accumulated in sheltered parts of large rivers and bays. In contrast, the other localities are of relatively small size and are situated at the base of steep slopes in young valleys, from which the creek flow has been restricted (see Plate X, Fig. 1). Consequently, the soil material derived as a result of natural erosion has accumulated and caused the development of these low-lying areas of impeded drainage.

The maps indicate that although most species are found in both areas, the species groupings at Bonnie Vale and Smith's Creek have little in common with one another or with sharply zoned mangrove and salt marsh communities. The results of a detailed examination of the relationship between species distribution and microtopography at Woollooware Bay and Bonnie Vale have already been reported (Clarke and Hannon, 1969).

The Bonnie Vale area (shown in Fig. 2) differs strikingly from the more usual species patterns in the following respects :

(i) *Avicennia* penetrates a long way inland from the Creek, some plants occurring in positions that are rarely (if ever) flooded by the tide. Some individuals are very large (7.6 m tall; 46 cm D.B.H.). Some show unusual features such as pneumatophore-like structures of 5–9 cm length projecting downwards from the trunks of the trees at distances from 2 to 6 m above ground level. Many *Avicennia* are unhealthy and large numbers of the "dwarf" form occur. Contrary to Hamilton's (1919) interpretation, these "dwarf" forms are thought to develop in areas of increased salinity.

(ii) *Aegiceras* is very abundant. The tallest individuals that have been found in Sydney (4 m) occur in an unmapped area in a dense thicket along a drainage channel, but located at quite a distance from the Creek. A very large number of small dead trees occur closer to the Creek (refer to map). Collins (1921) reported the burial of mangroves by sand in this area, and progressive elevation of the area caused by drift sand has probably led to a marked increase in salinity in this area. This may explain the death of some of the *Aegiceras*.

(iii) *Arthrocnemum* is sparse and unhealthy, except in more elevated positions, such as under *Casuarina* trees.

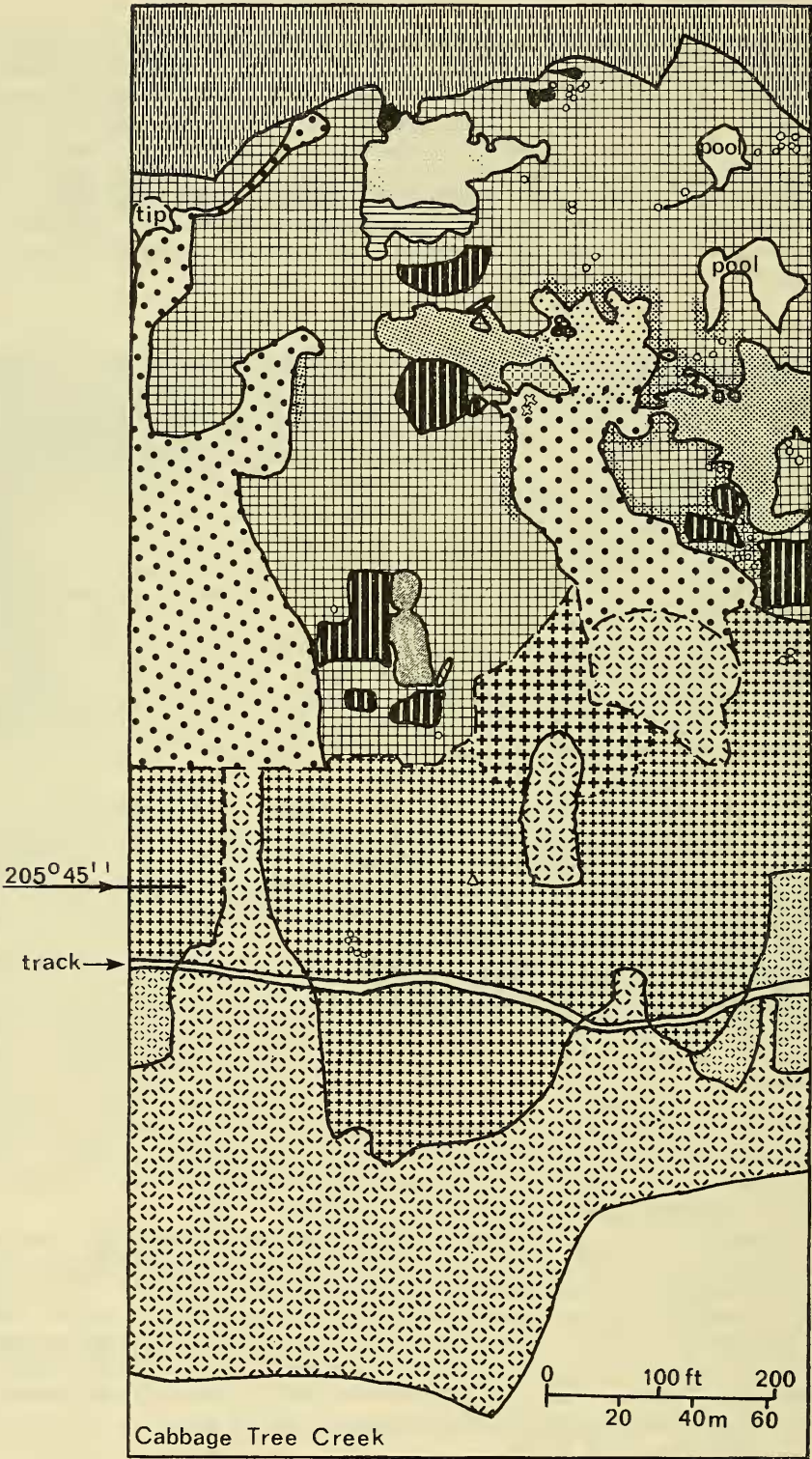
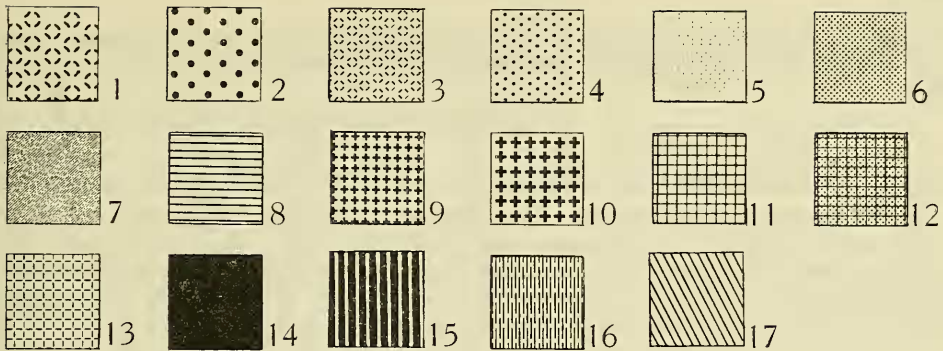


Fig. 2.—Vegetation distribution at Bonnie Vale.



KEY TO FIG. 2

Description of Community

1. A pure stand of *Avicennia*,* generally healthy with well developed pneumatophores. Few trees are in excess of 5 m in height and D.B.H. 20 cm; they are mostly about 2 m in height. The tallest trees are unhealthy.

2. This complex occurs along creek beds, and contains *Avicennia* (varying from 15 cm "dwarf" shrubs to trees 8 m high and D.B.H. 46 cm), *Aegiceras* (30–152 cm high) and *Arthrocnemum* with occasional patches of *Sporobolus* or *Samolus*. The *Avicennia* tends to occur at the centre of the creek-bed, and the *Aegiceras* and *Arthrocnemum* nearer the edge. In some cases *Arthrocnemum* occurs amongst *Avicennia* pneumatophores (but not where these are dense) and it is always sparse. Many of the *Avicennia*, especially the taller plants, are unhealthy, and the majority of the *Aegiceras* appear moribund, although some of the very small plants (30 cm) are healthy. The most landward mangroves are "outliers" which can be flooded by tide only rarely, if ever. However, they are exceptionally tall, and quite healthy. There are numerous bare patches.

3. This complex consists of dead *Aegiceras* and sporadic clumps of *Sporobolus*, and shows marked evidence of sand encroachment.

4. This community contains *Arthrocnemum* and *Sporobolus*, rarely in association, the latter genus being largely confined to the edges and elevated positions. Small *Aegiceras*, "dwarf" *Avicennia* and very sparse patches of *Samolus* may occur among the herbs.

5. This is a pure mat of *Arthrocnemum*, which is sparse and straggling and contains many bare patches.

6. A mixture of *Arthrocnemum* and *Sporobolus*, the latter being shorter than when associated with *Juncus*.

7. As above, but *Sporobolus* mostly occurs at the edges or in more elevated positions. Sparse *Samolus* is also present.

8. An *Arthrocnemum*-*Samolus* community with scattered clumps of *Juncus* and *Sporobolus*. In some spots, *Sporobolus* is not associated with *Juncus*.

9. This complex is very difficult to map successfully, as it contains all species except *Casuarina*, and the relative density of the components is very variable. It consists of stunted but healthy *Avicennia* scrub and most unhealthy *Aegiceras*, the latter predominating (death appears to be due to deposit of sand). In patches among the scrub occur *Arthrocnemum*, *Samolus* and *Sporobolus*, either together, or separately, and generally sparse. Thin patches of *Juncus* and *Sporobolus* also occur amongst the mangrove scrub, and there are many bare patches.

10. As above, but the clumps of *Juncus* are much larger, forming a thick sward in places, so that *Juncus* is the dominant species rather than mangrove.

11. This is a thick sward of *Juncus*, which is everywhere accompanied by tall *Sporobolus*.

12. As above, but scattered *Aegiceras* occurs at the perimeters.

13. As above, but containing more *Aegiceras* and less *Juncus*.

14. A mat of pure *Sporobolus*.

15. A stand of mature *Casuarina* with a dense understory of *Juncus* and *Sporobolus* and in some cases a few individual *Arthrocnemum*. The *Casuarina* average 6 m in height, but some individuals reach 9 m. The D.B.H. varies from 8 cm to 23 cm. None of the clumps is really dense, and dead trees are associated with most of the clumps. In a few cases young trees of adventitious origin occur at the edge of the stands.

16. This consists of tall, healthy *Casuarina* forming a border of varying width and merging into a community (dominated by *Livistona australis* and *Angophora costata*) at the base of a sandstone hill.

○ Isolated *Casuarina* tree.

× Isolated *Avicennia* tree.

△ 182·88 m marker peg on baseline.

17. This is a small group of young *Casuarina* (61–76 cm high) produced as adventitious outgrowths from trees in a nearby stand.

* All species names as in Clarke and Hannon (1967).

(iv) *Sporobolus* and *Juncus* occur at the seaward edge of the swamp, often abutting on to the mangroves. *Juncus* has a very extensive distribution in this area.

(v) *Casuarina* is stunted and mostly occurs in isolated clumps in slightly elevated positions throughout the marsh. Dead *Casuarina* stumps are found in areas now covered by *Juncus*, *Arthrocnemum* and, to a lesser extent, mangrove.

Cabbage Tree Creek enters the Port Hacking River about 0.8 km downstream to the north from the salt marsh area and at low tide sand spits almost completely sever the Creek from the River. Presumably this influences the amount of tidal inundation that occurs. The construction, in 1956, of a bridge across the Creek at the northern end of the marsh still further restricts the entry and exit of tidal water in the marsh area.

The diverse and unusual species associations are the outstanding features of the Smith's Creek area, as shown in Fig. 3. The *Casuarina* stands in this locality are quite unique due to the marked erosion of the areas they have occupied. Intersecting creeks have exposed part of the root systems, in some places to the extent that the trees have a very distinctly leaning habit (see Plate x, Fig. 2). Because of erosion and deposition amongst these stands, *Casuarina* occurs in a wide variety of very unusual species combinations, e.g., *Arthrocnemum-Triglochin-Casuarina-Aegiceras* form a community. Many dead *Casuarina* stumps occur, but no seedlings can be found. Adventitious propagation of shoots from lateral roots is very common (see Plate x, Fig. 3).

The differences in species groupings in these two localities are attributed, at least in part, to differences in tidal flow, accretion and erosion in these areas. Salinity may also be involved due to microtopographic differences (Clarke and Hannon, 1969).

Bonnie Vale and Smith's Creek have been selected since they are the only localities in this district where mangrove swamps and salt marshes occur within sanctuaries. Road building on the catchment areas above these sites provide a serious potential danger. Since it is intended that the areas will always be preserved in their natural state, the possibility therefore exists for future examination and detection of changes within these communities.

Long-term observations of areas are the most satisfactory means of determining whether a plant community has reached equilibrium with its environment. This would be of particular interest in these situations since it has been customary to attribute seral status to the communities occurring on tidal mud flats. Clarke and Hannon (in prep.) have not accepted this view for these communities in the Sydney district.

It appears that active accretion of sand has occurred and is continuing to occur at Bonnie Vale, whereas at Smith's Creek both vigorous erosion in certain parts of the area and deposition of material in other parts is apparent. These features at Smith's Creek are illustrated in Plate x, Figs 2 and 4. Changes may therefore be expected to occur with reasonable rapidity and can be examined in light of the predictions of Clarke and Hannon (in prep.). The rate of sediment accretion in any area is entirely dependent on local conditions and may therefore vary widely in different situations. However, the studies made by Chapman (1959) and Ranwell (1964) in British salt marshes where *Spartina* occurs indicate that the rates of accretion are such as to cause marked changes in vegetation pattern in periods of only 12–25 years, and even less in some instances (Boorman, 1971).

In contrast, the chances of preservation of the Woollooware Bay area are remote—it is likely that all the extensive areas of mud flats will be destroyed in the near future. Denudation of quadrats in the ecotones at Woollooware Bay was followed by re-establishment of vegetation similar to the original cover,

even though after three years the quadrats could still be readily distinguished from the adjacent undisturbed areas (Clarke and Hannon, in prep.). Regeneration of the same cover indicates that the present zonation is reflecting an equilibrium with the prevailing conditions.

II. COMMUNITY VARIATION IN SOUTHERN AUSTRALIA

The observations that have been made in other areas are summarized in Table 1 to show the many differences that occur in these communities. It is apparent that many features concerning the distribution pattern of these species are not understood. The differences between the communities at Bunbury and the other Western Australian areas examined suggest that comparative studies of these communities would be particularly interesting.

Arthrocnemum arbuscula, *A. halocnemoides* and *Atriplex* sp. that occur in the South Australian maritime communities are also found inland from the coast in non-tidal areas on clay soils of high salt content, and with halite crystals on the soil surface, as well as at intervals across the Nullarbor Plain and as far west as Norseman in Western Australia. At Eucla, they occur on the lee side of calcareous maritime sand dunes and *A. arbuscula* usually is the dominant species fringing the salt lakes between Norseman and Esperance. It is apparent that these species are not only salt-tolerant, but also capable of existing under more xeric conditions than those prevailing in the maritime communities.

The wide variety of soil types on which these communities occur is of interest, particularly since in Chapman's (1960) classification of salt marshes the northern European and western Atlantic groups are subdivided on the basis of soil types. It appears that edaphic conditions are relatively unimportant in these Australian communities, at least in comparison to tidal influence, and the inland occurrences of *Avicennia* (Beard, 1967) and *Arthrocnemum* species indicate that even tides are not an essential, even though a usual component of the environment of these species.

GENERAL DISCUSSION

Comparison of these communities with those in similar habitats in other parts of the world shows differences and indicates that the variation occurring in Australia is not atypical. While *Distichlis* occurs from latitudes just south of Sydney in South Australia, Victoria and Tasmania, it appears to be absent from Western Australia as in New South Wales. Extensive development of grasses is a feature of the majority of Northern Hemisphere marshes. In addition, the zonal pattern of phanerogam distribution is a near-universal feature of salt marsh vegetation and is the chief reason for the seral interpretation that has generally been attributed to their component communities.

Furthermore, the Sydney district is one of the few localities in which well-developed examples of mangrove swamps and salt marsh communities occur in close association. In northern Australia, mangrove swamps dominate the maritime areas, but further south fewer species of mangroves can establish themselves successfully and salt marshes develop behind a frontal zone of *Avicennia* and *Aegiceras*. Still further south, mangroves are completely replaced by salt marshes. A similar situation is found in Florida and between the north and south islands of New Zealand (Chapman, 1960). Clarke and Hannon (in prep.) have proposed that in the Sydney district the mangrove and salt marsh flora grow in conjunction, but not as a succession as was originally suggested by Pidgeon (1940). In addition, no evidence has been obtained for the Sydney district that mangrove species are prograding the shoreline. However, McNae's (1966) descriptions of the relative positions occupied by seedlings and adults of

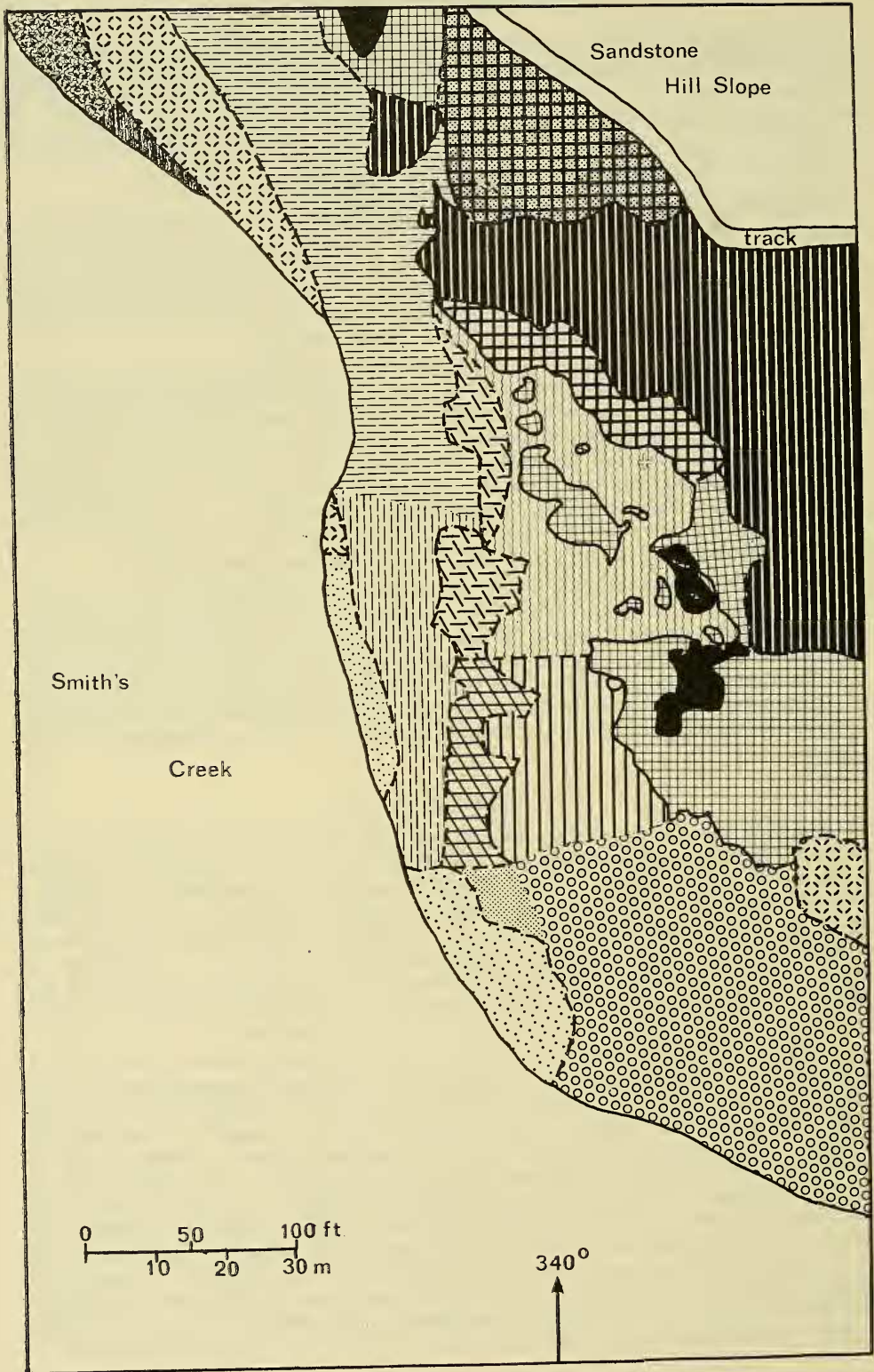
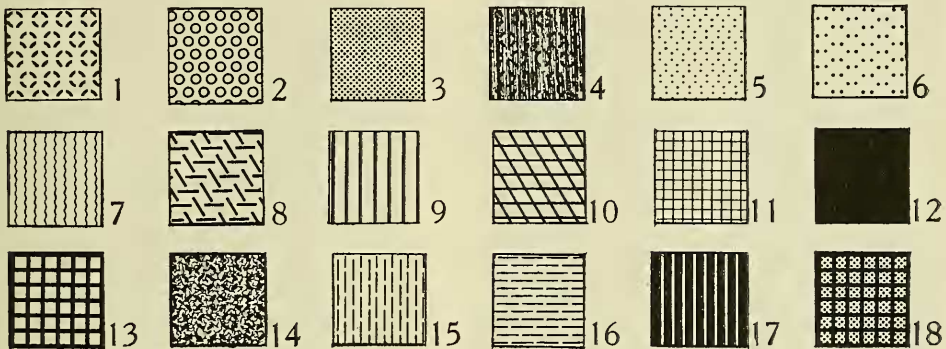


Fig. 3. Vegetation distribution at Smith's Creek.

Avicennia marina in Queensland and the relative stability of the rooting medium in these positions support the view that in that area *Avicennia* is effective in trapping silt, which is the role typically attributed to mangroves.

It is obvious that stands of these tide-affected communities should be preserved in many areas to perpetuate the considerable ecological and genotypic variation that occurs, even between geographically close localities within Australia as well as for the features that distinguish them from their counterparts in many areas of the world.



KEY TO FIG. 3

1. A community of *Avicennia* averaging about 5 m in height, although some individuals reach 8 m. It is bordered by *Aegiceras* up to 1.5 m high.

2. A very mixed community containing (1) a poorly demarcated patch of *Casuarina* (up to 5–6 m high and D.B.H. 10 cm), with occasional patches of *Arthrocnemum* beneath it. There is evidence of both erosion and deposition in this area. Most of the *Casuarina* are adventitious in origin; (2) a few “dwarf” *Avicennia*; (3) numerous scattered *Aegiceras* ranging from seedlings to trees 1.7 m high; (4) patches of *Samolus* and *Triglochin* of variable density.

3. A mat of *Samolus* and *Triglochin* (largely separate), with a few scattered *Aegiceras*.

4. A mat in which *Samolus* mingles with a *Sporobolus* sward.

5. A *Sporobolus* community with *Aegiceras* scattered throughout.

6. As above, but very few *Aegiceras* occur.

7. A patchy *Arthrocnemum* and *Triglochin* community (the two genera occurring both separately and together) with scattered *Aegiceras* up to 1.5 m high.

8. As above, but *Casuarina* is also present.

9. An *Arthrocnemum*-*Triglochin* community, as described above. Neither *Aegiceras* nor *Casuarina* is present.

10. An *Arthrocnemum*-*Triglochin* community as described above, containing *Casuarina* but not *Aegiceras*.

11. A *Juncus* community associated with sporadic patches of *Sporobolus*.

12. Pure *Sporobolus*.

13. A *Cladium*-*Sporobolus* community.

14. *Casuarina* with *Sporobolus* understory.

15. *Casuarina* with *Cladium*-*Sporobolus* understory, *Sporobolus* dominant.

16. *Casuarina* with *Cladium*-*Sporobolus* understory, *Cladium* dominant.

17. A *Casuarina* community with a *Juncus* understory, and sporadic patches of *Sporobolus* occur among the *Juncus*. The *Casuarina* reach a maximum of 9–12 m and a D.B.H. of 8–13 cm.

18. A *Cladium*-*Sporobolus*-*Phragmites* community.

× Isolated *Avicennia* tree.

+ Isolated *Aegiceras* bush.

References

- BEARD, J. S., 1967.—An Inland Occurrence of Mangrove. *West. Aust. Nat.*, 10: 112–115.
- BOORMAN, L. A., 1971.—Studies in Salt Marsh Ecology with special reference to the Genus *Limonium*. *J. Ecol.*, 59: 103–120.
- CHAPMAN, V. J., 1959.—Studies in Salt Marsh Ecology. IX. Changes in Salt Marsh Vegetation at Scott Head Island. *J. Ecol.*, 47: 619–639.
- , 1960.—*Salt Marshes and Salt Deserts of the World*. Leonard Hill Ltd., London. 392 pp.
- CLARKE, LESLEY D., and HANNON, NOLA J., 1967.—The Mangrove Swamps and Salt Marsh Communities of the Sydney District. I. Vegetation, Soils and Climate. *J. Ecol.*, 55: 753–771.
- , 1969.—The Mangrove Swamps and Salt Marsh Communities of the Sydney District. II. The Holocene Complex with particular reference to Physiography. *J. Ecol.*, 57: 213–234.
- , 1970.—The Mangrove Swamps and Salt Marsh Communities of the Sydney District. III. Plant Growth in relation to Salinity and Waterlogging. *J. Ecol.*, 58: 351–369.
- , 1971.—The Mangrove Swamps and Salt Marsh Communities of the Sydney District. IV. The Significance of Species Interaction. *J. Ecol.*, 59: 535–553.
- COLLINS, MARJORIE I., 1921.—On the Mangrove and Salt Marsh Vegetation near Sydney, N.S.W., with special reference to Cabbage Tree Creek, Port Hacking. *PROC. LINN. SOC. N.S.W.*, 46: 376–392.
- CURTIS, W., and SOMERVILLE, J., 1947.—Boomer Marsh—a preliminary Botanical and Historical Survey. *Proc. Roy. Soc. Tas.*, 151–157.
- HAMILTON, A. A., 1919.—An Ecological Study of the Salt Marsh Vegetation of the Port Jackson District. *PROC. LINN. SOC. N.S.W.*, 44: 463–513.
- MCAURTHUR, W. M., 1957.—The Plant Ecology of Garden Is. in relation to the Neighbouring Islands and Adjacent Mainland. *J. Roy. Soc. W.A.*, 40: 46–64.
- MCAE, W., 1966.—Mangroves in Eastern and Southern Australia. *Aust. J. Bot.*, 14: 67–104.
- PIDGEEON, ILMA M., 1940.—The Ecology of the Central Coastal Area of New South Wales. III. Types of Primary Succession. *PROC. LINN. SOC. N.S.W.*, 65: 221–249.
- RANWELL, D. S., 1964a.—*Spartina* Salt Marshes in Southern England. II. Rate and Seasonal Pattern of Sediment Accretion. *J. Ecol.*, 52: 79–94.
- , 1964b.—*Spartina* Salt Marshes in Southern England. III. Rates of Establishment, Succession and Nutrient Supply at Bridgwater Bay, Somerset. *J. Ecol.*, 52: 95–105.
- SAUER, J. D., 1965.—Geographic Reconnaissance of Western Australian Seashore Vegetation. *Aust. J. Bot.*, 13: 39–69.
- STEENSON, J., and BARRATT, T., 1970.—Field Survey of Saline Mud Flats, Smith's Creek, Ku-ring-gai Chase. *J. Nat. Pks.*, Sept., 11–14.
- WOOD, J. G., 1937.—Vegetation of South Australia. Handbook of Flora and Fauna of S.A. Govt. Printer, Adelaide.

EXPLANATION OF PLATE X

Fig. 1. Salt marsh developed at base of sandstone hill. Salt marsh genera present are *Juncus* (background), *Aegiceras* on a mat of *Samolus*, *Casuarina* (right middle ground), patches of *Sporobolus* (foreground) interspersed with deposits of sand.

Fig. 2.—Erosion in mature *Casuarina* stand at Smith's Creek. White dowel sticks are for measurement of accretion rate.

Fig. 3. Adventitious development of *Casuarina*. Note mangrove adjacent to *Casuarina*, on the left side.

Fig. 4. Deposition of sand at Smith's Creek. Note mounds covered by *Arthrocnemum*, and large numbers of dead *Casuarina* stumps.

LOCATION OF THE EXTERNAL REFERENCE MARKERS

Bonnie Vale

1. Zero on the base line is marked by the steel peg at 8.08 m from the fire hydrant (at 213°), located at approximately 158.50 m from the concrete block supporting the eastern end of the bridge spanning Cabbage Tree Creek.

2. A steel peg is located at 182.88 m from zero along the base line (205° 45').

3. A painted triangle is marked on a prominent sandstone boulder on the hillslope above the marsh at a bearing of 115° 45' from the 192.33 m point on the base line.

Smith's Creek

1. Zero on the base line is marked by a painted vertical groove of 59 cm length on a sandstone boulder. This boulder is on the northern side of the track at 0.24 km east from the base of the hill. It is opposite the first extensive patch of *Arthrocnemum* in the marsh.

2. A steel peg is located at 30.5 m from zero along the base line (160°).

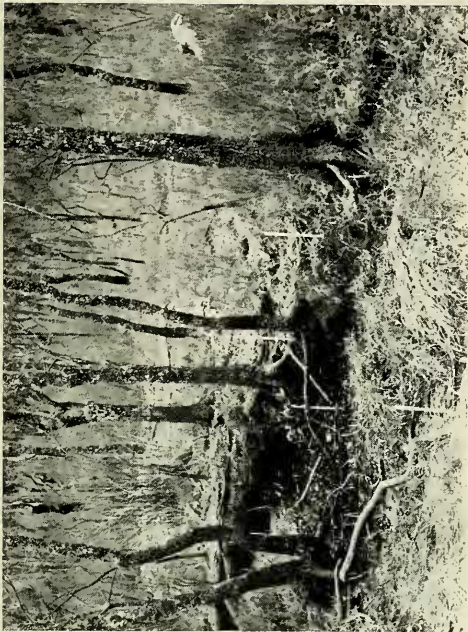


Fig. 2.



Fig. 4.

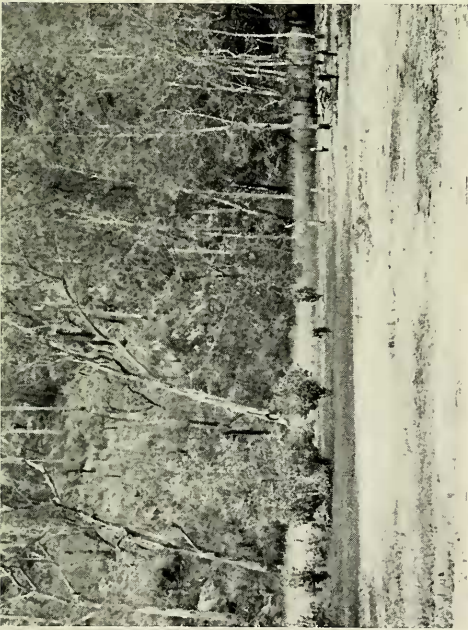


Fig. 1.



Fig. 3.

TABLE 1
A Comparison of the Mangrove and Salt Marsh Communities in Several Areas of Southern Australia

	Sydney, N.S.W.	Northern N.S.W.— Gosford to Coff's Harbour*	Victoria†	Hobart, Tasmania	South Australia	South-Western Australia
Soil parent material	Triassic Sandstone	Quaternary Alluvial deposits	Primary Quaternary Sands and Clay Silts.	Mudstone — oc- casional Dolerite	Tertiary Limestone	Quaternary Limestone
Soil texture	.. Sand	Sand	Sandy clay to clayey or silty sand, overlain in <i>Arthrocnemum</i> zone by fibrous peat layer of 5-15 cm depth	Clay loam	Heavy clay	Sandy loam—light clay
Yearly mean max temp (C)‡ ..	21.7	—	19.8	16.7	22.8	23.1
Yearly mean min temp (C)‡ ..	13.4	—	10.0	8.3	11.8	13.1
Mean yearly rain- fall (cm)‡ ..	113.79	—	65.76	63.58	53.57	91.41
Highest recorded annual rainfall (cm)‡ ..	219.28	—	96.62	110.21	78.61	133.78
Lowest recorded annual rainfall (cm)‡ ..	58.45	—	39.65	39.17	28.75	50.80

GENUS or SPECIES

<i>Avicennia marina</i> var. <i>resinifera</i>	Abundant, trees and shrubs	As for Sydney	Western Port — dense thicket 2-4 m tall with smaller forms more widely spaced on landward and sea- ward margins Many seedlings through- out zone, which varies from 9 to 367 m width, but which is generally 46-55 m wide. On the northern and western inner shores and islands and on the sheltered areas of French Island and Philip Island <i>Port Phillip Bay</i> — localized occurrences along western shore <i>Corner Inlet</i> —scattered bushes, 61-91 cm tall at several localities	Absent	Abundant, healthy shrubs <i>Pt. Adelaide</i> — dense thicket 5 m tall, few seed- lings, except at edges, pneumatophores up to 61 cm tall <i>Pt. Gawler</i> — oc- casional trees, up to 6 m; dark scaly bark; healthy dense shrubs; "dwarf" forms (away from water's edge) <i>Pt. Wakefield</i> —few stunted shrubs up to 3 m high; restricted to water's edge; few pneumatophores <i>Spencer's Gulf</i> — shrubs up to 2 m at <i>Pt. Pirie</i> and <i>Pt. Augusta</i> , ab- sent elsewhere <i>Ceduna</i> — few straggling shrubs 1.2 m tall	<i>Bunbury</i> —diseased shrubs up to 5 m <i>Mandurah</i> —absent <i>Perth, Swan River</i> — absent
<i>Aegiceras cornicu- latum</i>	Relatively few by comparison with <i>Avicennia</i>	More abundant than in Sydney	Absent	Absent	Absent	Absent
<i>Arthrocnemum aust- ralasicum</i>	Abundant	Less abundant than in Sydney	Abundant, mingling with landward fringe of mangroves and ex- tending to <i>Melaleuca</i> zone; sparse where <i>A. arbuscula</i> is prom- inent	Abundant, pure stand at water's edge	Occurs only at <i>Pt. Augusta</i> and <i>Ceduna</i> immedi- ately landward to and sharply zoned from the mangroves	<i>Bunbury</i> —abun- dant <i>Mandurah, Perth, Swan River</i> —less abundant than in Sydney
<i>Arthrocnemum ar- buscula</i> (R.Br.) Moq.	Absent	Absent	<i>Western Port</i> — com- monly occurs as dense sward 1.5-2.4 m tall in well drained situa- tions and as scattered individuals 15 cm-1 m tall with dense <i>A. aust- ralasicum</i> and <i>Samolus</i> in more waterlogged areas; does not extend as far seaward as <i>A. aust- ralasicum</i> ; sharply zoned from <i>Stipa</i>	Abundant	Abundant, 2 m tall at <i>Pt. Wake- field</i> , sharply zoned from man- groves; land- ward from <i>A. aust- ralasicum</i> at <i>Pt. Augusta</i> and <i>Ceduna</i>	<i>Bunbury</i> —absent <i>Mandurah, Perth, Swan River</i> —less abundant than in South Australia

* At Erina, near Gosford, the vegetation is similar to that at Woolooware Bay.

† Information for Victoria has been supplied by Dr. D. H. Ashton, Botany School, University of Melbourne, Victoria. Dr. Ashton also notes that *Hemichroa pentandra* R.Br., *Statice australis* Spreng. and *Samolus repens* are common in Victorian marshes associated with *Arthrocnemum* sp. and that a bare zone commonly separates *Arthrocnemum* sp. from the *Stipa* zone.

‡ The climatic data are based on records collected over the period 1911-1940 in the capital city of each State.

§ This species requires revision.

TABLE 1—Continued
A Comparison of the Mangrove and Salt Marsh Communities in Several Areas of South Australia—Continued

	Sydney, N.S.W.		Northern N.S.W.— Gosford to Coff's Harbour*	Victoria†	Hobart, Tasmania	South Australia	South-Western Australia
<i>Arthrocnemum halocnemoides</i> Mees	Absent		Absent	Locally common, usually landward of <i>A. arbuscula</i> , where both species occur	Present	Abundant, sharply zoned from <i>A. arbuscula</i> at Pt. Augusta and Ceduna	Bunbury—absent. <i>Mandurah</i> , <i>Perth</i> , <i>Swan River</i> —less abundant than in South Australia
<i>Atriplex</i>	<i>A. patula</i> L. occurs, but is very uncommon		Absent (?)	<i>A. patulosa</i> R.Br. is locally common in some parts of Western Port, where it is more prominent than in other localities; occurs landward to <i>A. arbuscula</i> in more elevated positions	Absent	<i>A. patulosa</i> and <i>A. stipitata</i> Benth. abundant in more elevated positions. Recorded by Wood (1937) as components of drier communities	<i>A. patulosa</i> recorded by McArthur (1957)
<i>Triglochin</i>	<i>T. striata</i> fairly common		Less abundant than in Sydney	<i>T. striata</i> scattered throughout <i>A. australasicum</i> , <i>A. arbuscula</i> and <i>A. halocnemoides</i>	Uncommon. <i>T. striata</i> recorded by Curtis and Somerville (1947)	Absent	Bunbury—absent. <i>Mandurah</i> — <i>T. mucronata</i> R.Br. fairly common, forming carpet under <i>Casuarina</i>
<i>Suaeda</i>	<i>S. australis</i> — sporadic, uncommon		Absent (?)	<i>S. maritima</i> L. — scattered individuals occur from landward edge of mangroves to <i>Stipa</i> , or bare zone in front of <i>Stipa</i>	<i>S. maritima</i> § uncommon. Recorded by Curtis and Somerville (1947)	Absent	<i>S. australis</i> — uncommon except at Bunbury
<i>Sporobolus virginicus</i>	Abundant		Less abundant than in Sydney, directly landward to mangroves	Rare	Absent (?)	Recorded by Wood (1937) as component of wetter areas, but now apparently cleared	Uncommon except at Bunbury
<i>Juncus maritimus</i> var. <i>australiensis</i>	Abundant		Abundant, occurs landward of either mangroves or <i>Sporobolus</i>	Uncommon. Western Port, Port Phillip — occurs with <i>Stipa</i> (which appears to be its equivalent in Victoria) and <i>Cladium filum</i> , § or as scattered clumps amongst <i>A. arbuscula</i> and <i>A. halocnemoides</i>	Uncommon, recorded by Curtis and Somerville (1947)	Recorded by Wood (1937) in wetter areas, but now apparently cleared	Less abundant than in Sydney, except at Bunbury
<i>Cladium</i>	<i>C. junceum</i> common	un-	Absent (?)	<i>C. filum</i> § R.Br. uncommon. Western Port, Port Phillip — occurs in association with <i>Stipa</i>	<i>C. filum</i> § uncommon. Recorded by Curtis and Somerville (1947)	<i>C. junceum</i> and <i>C. filum</i> § recorded by Wood (1937) in wetter areas now apparently cleared	Absent
<i>Distichlis</i>	Absent		Absent	<i>D. disticophylla</i> (Labill.) Fassett. Western Port, Corner Inlet — abundance variable; may be associated with <i>A. australasicum</i> or with <i>Stipa</i> , <i>Cladium</i> and <i>Juncus</i>	<i>D. disticophylla</i> abundant, dominating the grass-rush-sedge community	<i>D. spicata</i> (L.) Greene recorded by Wood (1937) in wetter areas now apparently cleared	Absent
<i>Casuarina</i>	<i>C. glauca</i> abundant		<i>C. glauca</i> abundant	Absent. <i>Melaleuca ericifolia</i> Smith thickets are the local equivalent of this zone	Absent	<i>C. stricta</i> Ait. recorded by Wood (1937) as climax on coast, where rainfall exceeds 51 cm; now apparently cleared	<i>C. glauca</i> — less abundant than in Sydney

* At Erina, near Gosford, the vegetation is similar to that at Wooloware Bay.

† Information for Victoria has been supplied by Dr. D. H. Ashton, Botany School, University of Melbourne, Victoria. Dr. Ashton also notes that *Hemichroa pentandra* R.Br., *Statice australis* Spreng. and *Somolus repens* are common in Victorian marshes associated with *Arthrocnemum* sp. and that a bare zone commonly separates *Arthrocnemum* sp. from the *Stipa* zone.

‡ The climatic data are based on records collected over the period 1911–1940 in the capital city of each State.

§ This species requires revision.